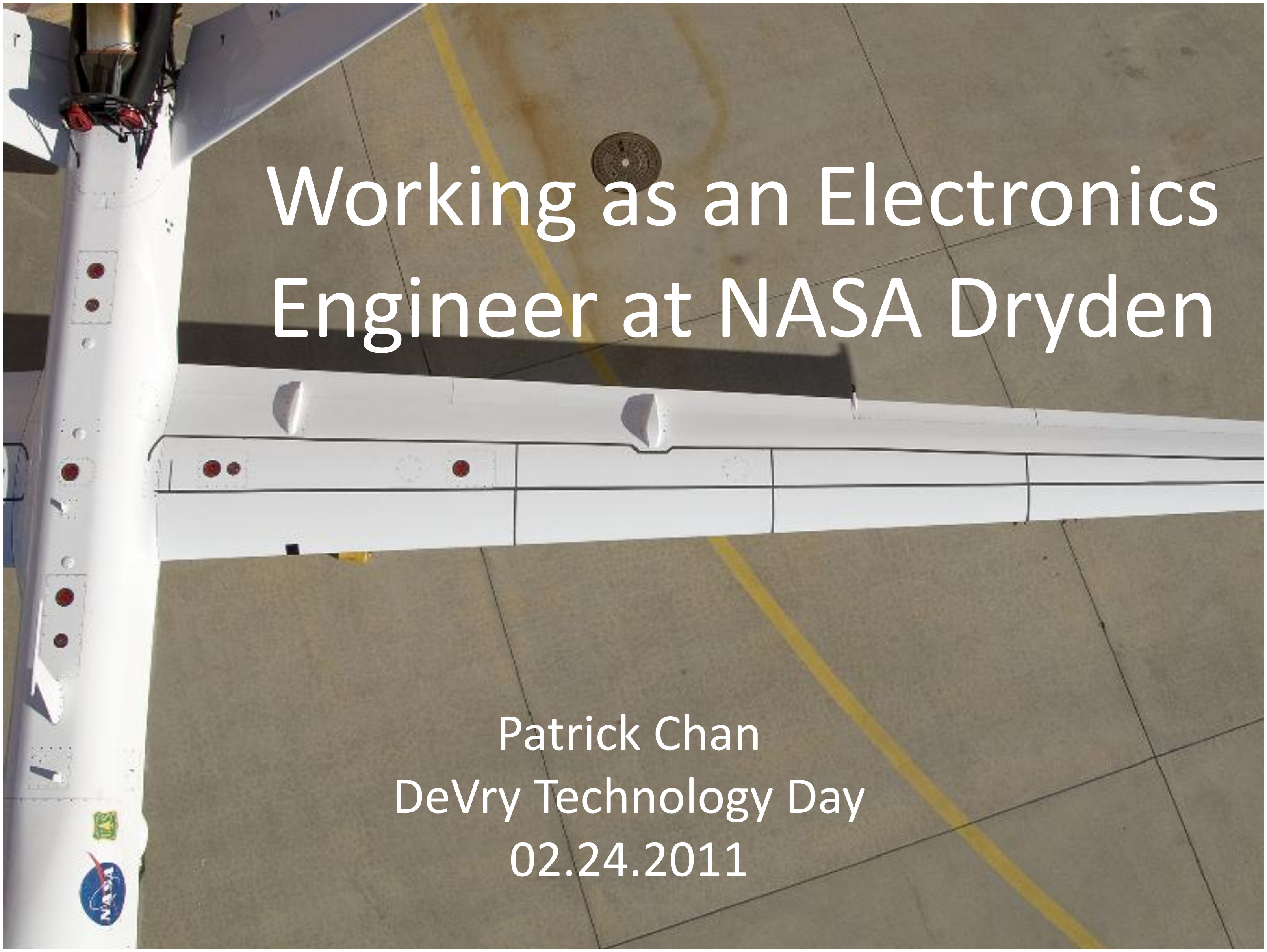


Working as an Electronics Engineer at NASA Dryden

Patrick Chan

DeVry Technology Day

02.24.2011

Who am I?

- Immigrated from Macau at age 10
- Educated in US since 5th Grade
- Attended University of California, Irvine
  - BS Chemical Engineering (2001)
  - MS Material Sciences (2002)
  - PhD Inter-disciplinary Studies (2009)
    - Material Sciences and Electric Engineering
    - Thesis: "Fabrication and Development of CO_2 Laser-Written Long Period Fiber Gratings and its Application to Vibration Measurement"
- Worked at NASA since June 2009

What do I do?

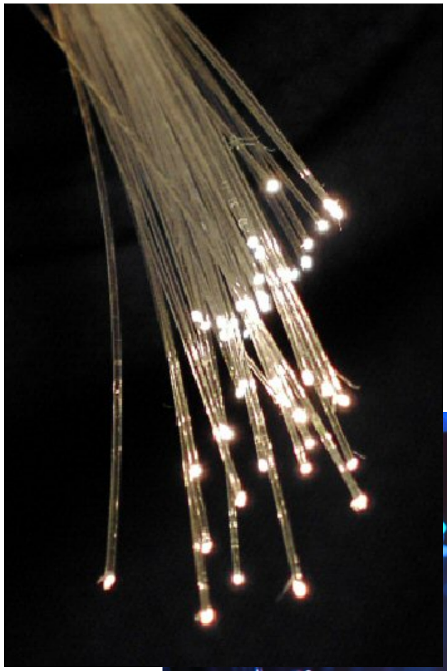
- Electronics Engineer at NASA Dryden Flight Research Center (DFRC)
- Using fiber optics as an environmental sensor for aerospace and numerous other applications

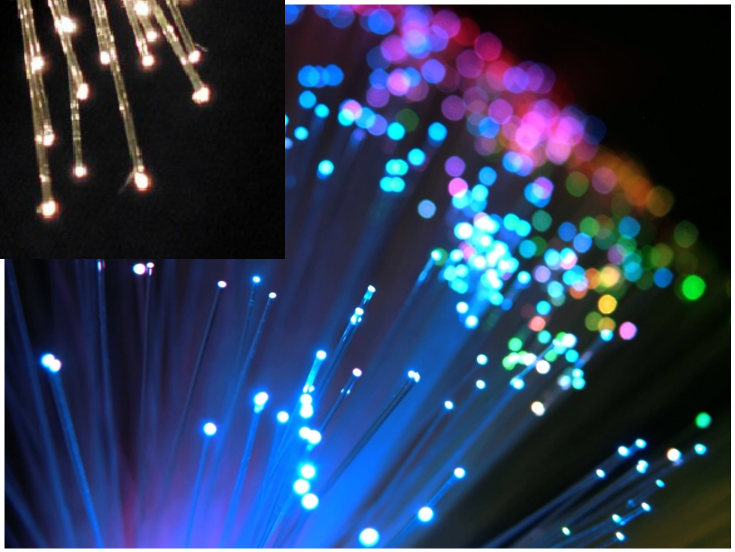
NASA Dryden Flight Research Center

- Located Edwards AFB in Southern California
  - 1.5 Hours drive from LA
  - We are the A (Aeronautics) of NASA
  - http://www.youtube.com/watch?v=4C_prwMkRKQ

What is Fiber Optics?

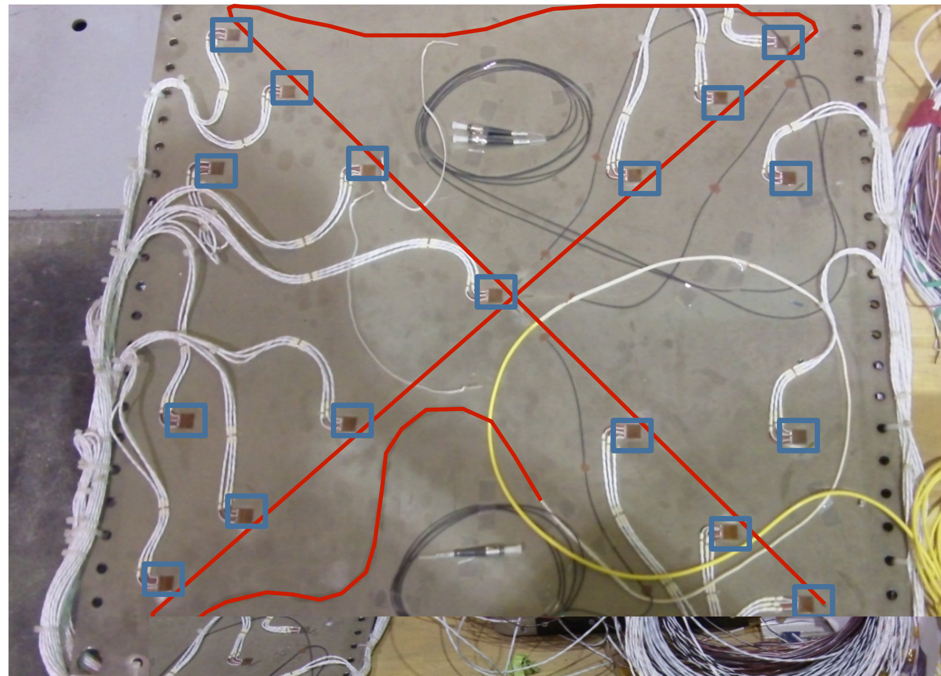
- Optical Fiber:
  - a dielectric waveguide which guide light throughout its length via total internal reflection
- Light can propagate in miles without signal degradation
  - Backbone of today's internet
  - Can be also used as environmental sensors

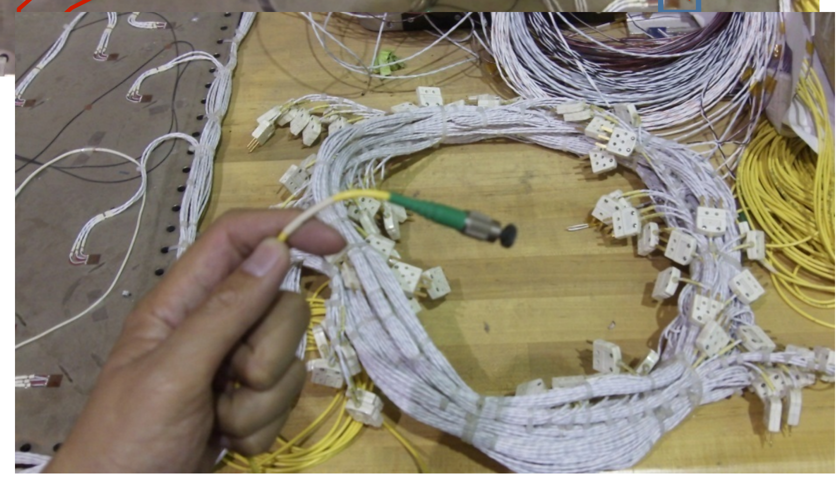




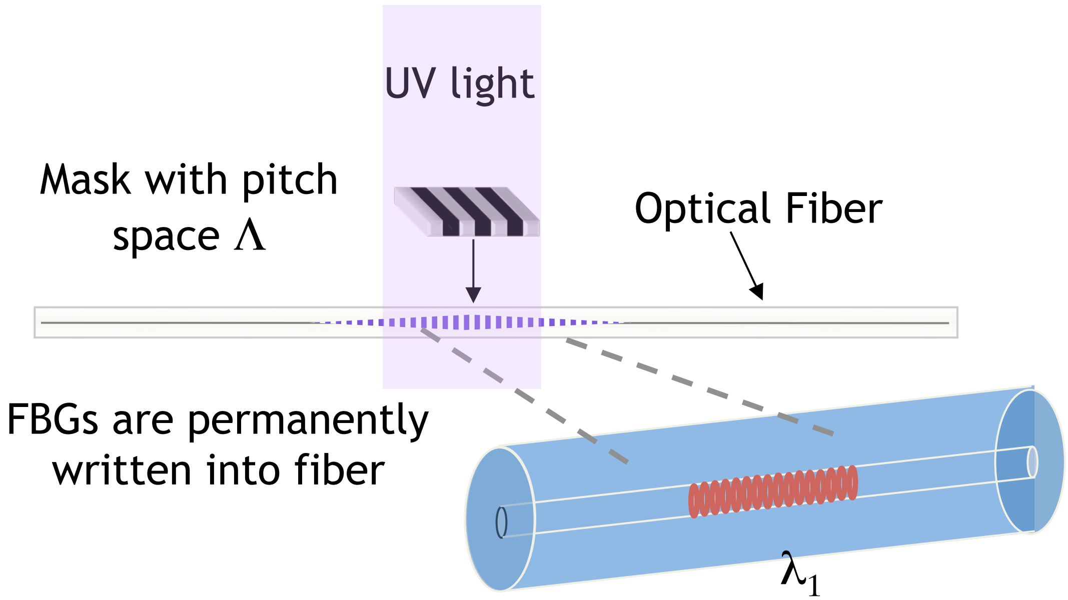
Why Use Fiber as sensors?

- Immunity to electromagnetic interference, radio-frequency interference, and radiation.
- Compact, lightweight, ruggedized device for smart structure
  - Embedded into structure
  - Harsh environment (under water)
- The ability to be multiplexed. (100s of sensors on a single fiber).
- Ease of installation and use (single fiber vs. multitude of lead wires).
- Potential low cost as a result of high-volume telecommunications manufacturing.
- WEIGHT SAVING vs Strain gauge





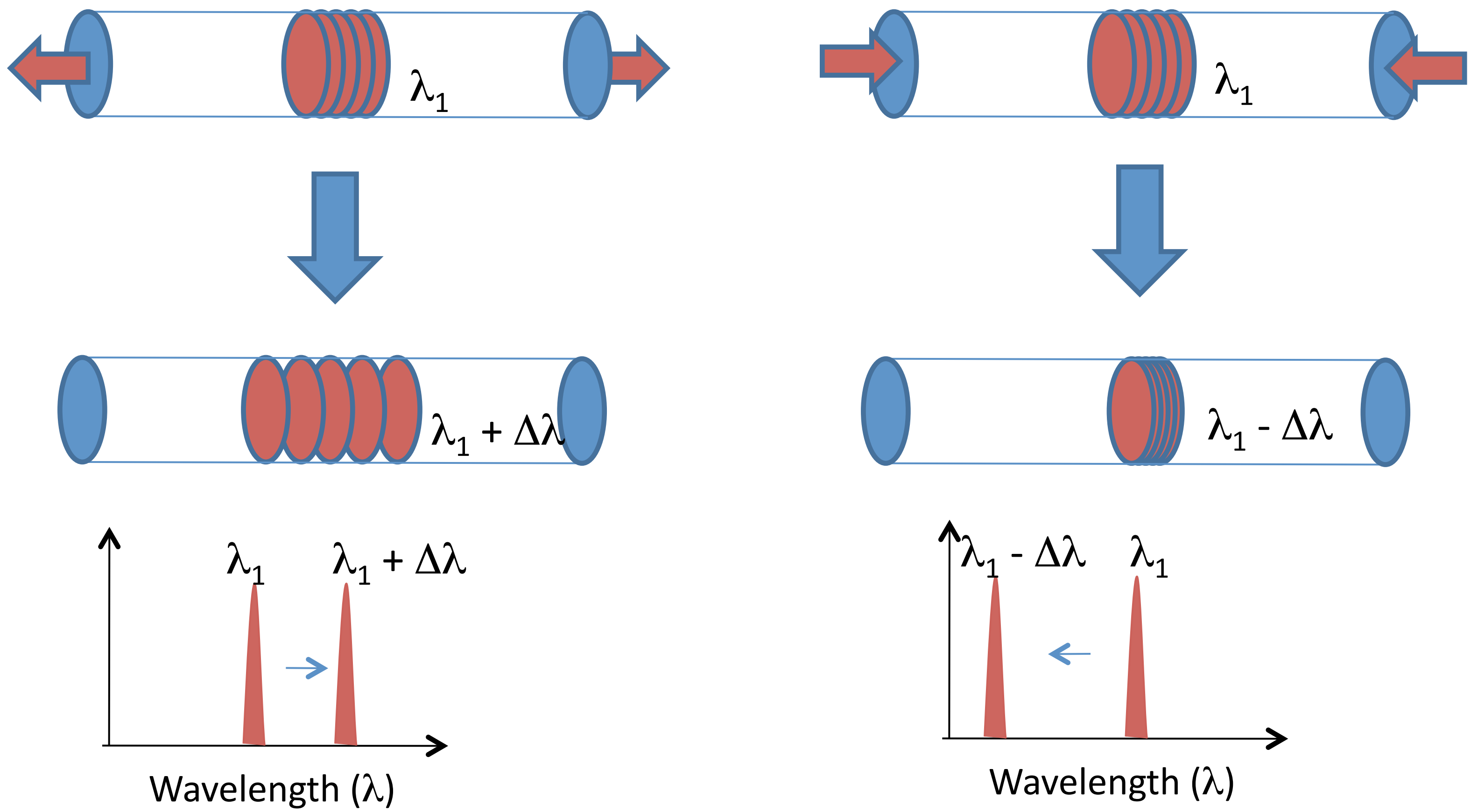
How are these fiber sensors (FBG) fabricated?



- UV light is absorbed uniformly to the Ge-doped fiber core through phase mask
- The periodic index change results in grating (sensing) effect
- Each sensor acts as an miniature mirror that reflects light at a particular wavelength (λ)

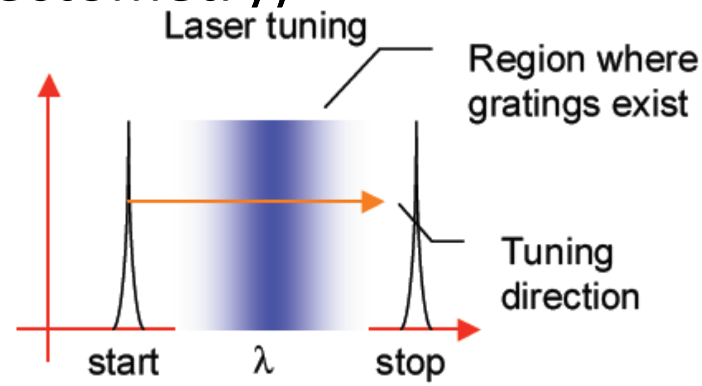
How do FBG sensors works?

- Like an accordion



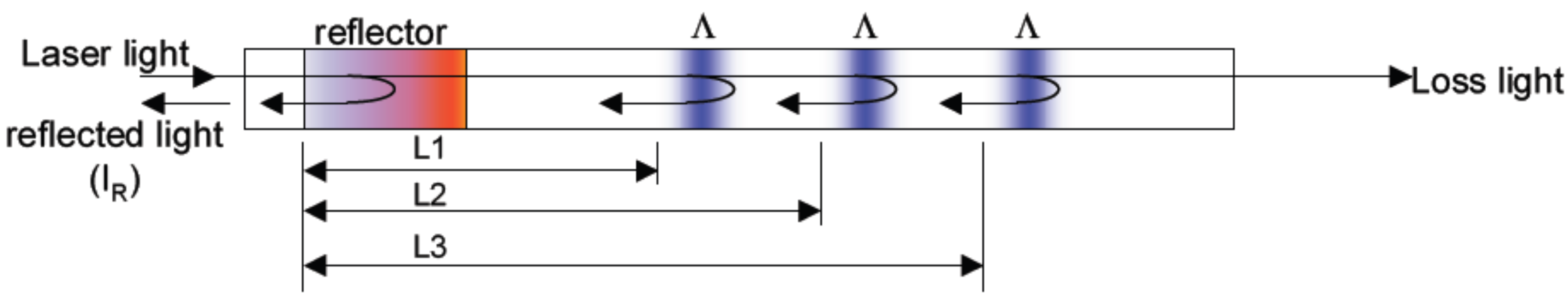
NASA patented Grating Modulation Multiplexing Method (Optical Frequency Domain Reflectometry)

- Multiplex 100s of sensors onto one fiber.
- All gratings are written at the same wavelength.
- A narrowband wavelength tunable laser source is used to interrogate sensors.
- Each sensor is only ½ inch long

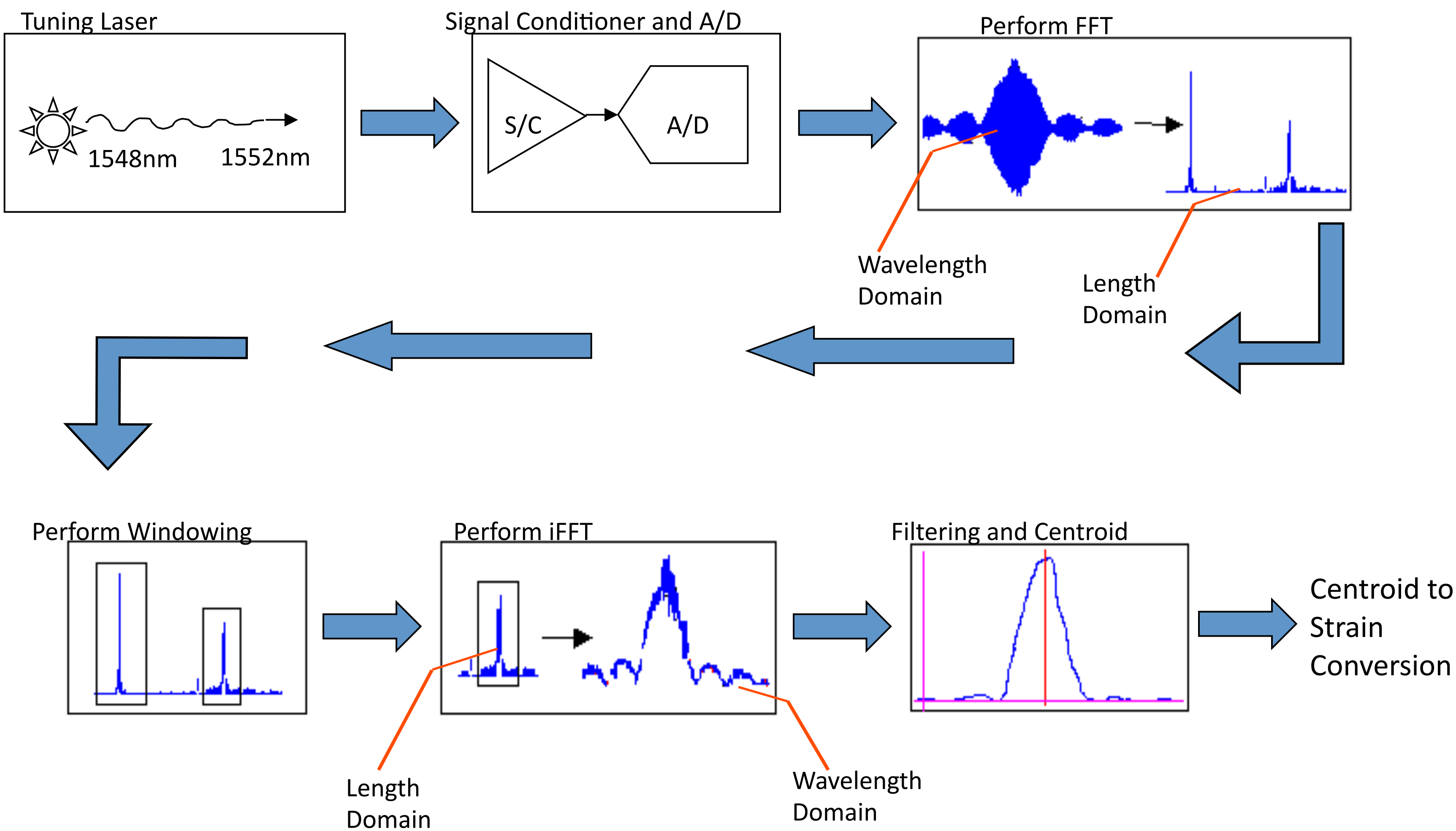


$$I_R = \sum_i R_i Cos(k2nL_i) \qquad k = \frac{2\pi}{\lambda}$$

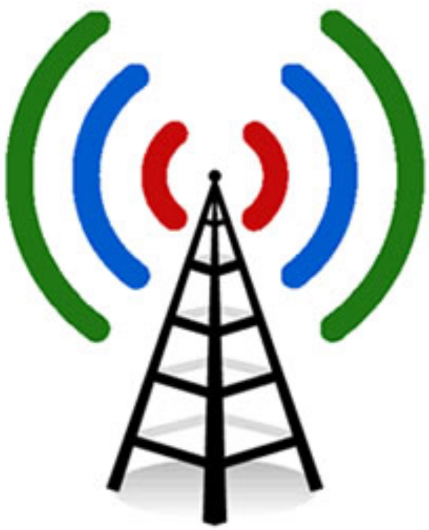
R_i – spectrum of i^{th} grating
n – effective index
L – path difference
k - wavenumber



Processing Procedure (Complete picture)



Layman's Term: Tuning your favorite radio station!



Multiple frequencies
are broadcasted on airwave

Radio receives ALL frequencies

Radio tuner accepts ONE frequency

Radio analogy to Optical Frequency Domain Reflectometry

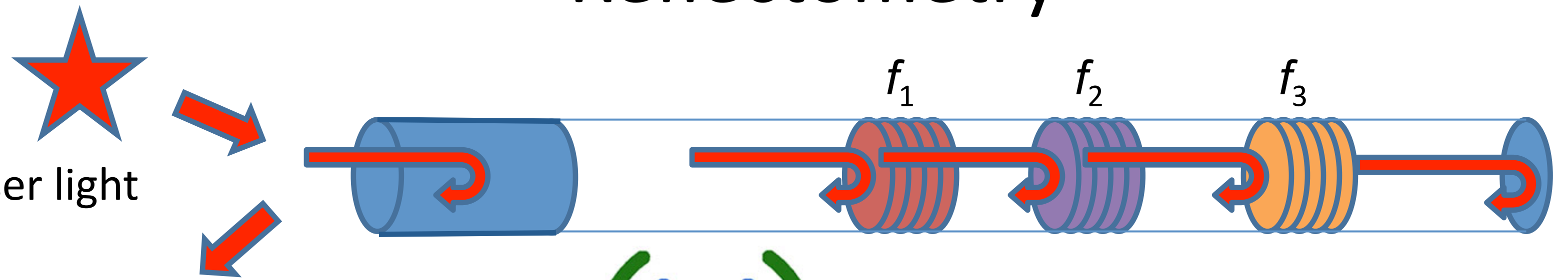


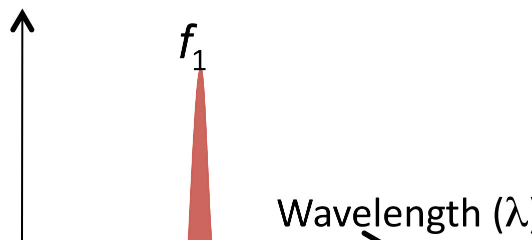
Photo-detector

(Receive ALL sensor signal)

97.3 97.7 98.1

Sensor Frequency ID
(Broadcast Tower)
Determined via location of sensor

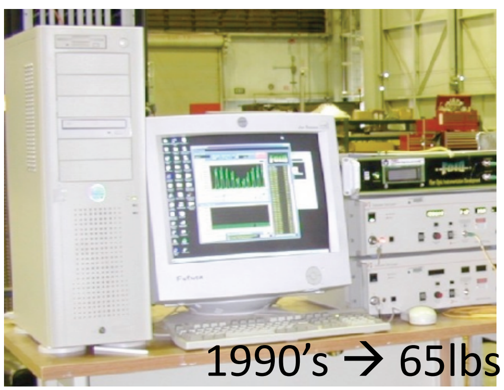
(Radio Receiver)



FFT/iFFT to “dial in” to particular sensor information
(Radio Tuner)

NASA Dryden's role in fiber sensing technology

- Technology is first pioneered/ patented at NASA Langley Research Center (LaRC) during the late 90's:
  - Laboratory-based system
  - One sample being taking every 30 second (one channel).
- NASA Dryden miniaturized and developed an "one-box system" for aerospace application
  - Compact system for flight or ground test
  - Patent pending algorithm improved sampling rate to 100 samples per second (multiple channels)

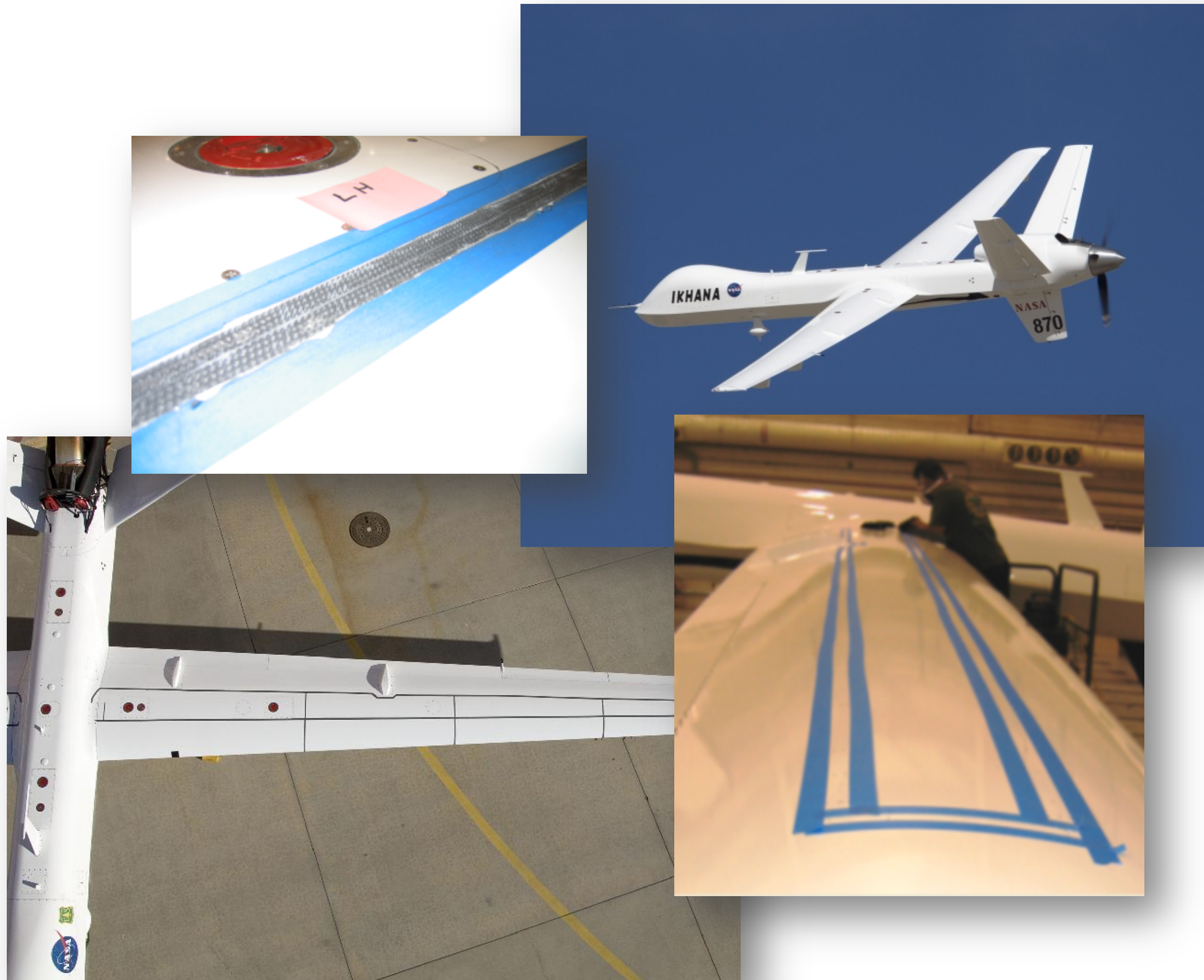

1990's → 65lbs


2008 → 23lbs

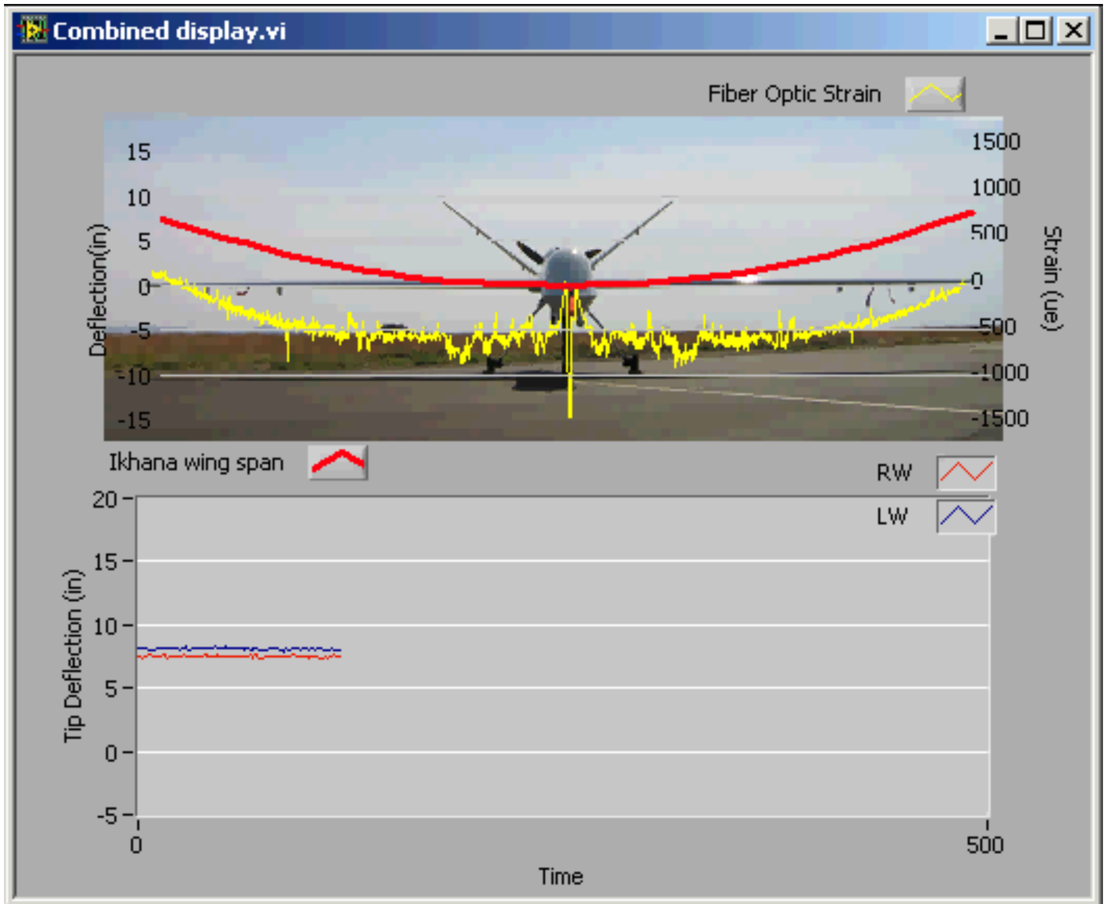
Project: Ikhana

- Ikhana is NASA Dryden's version of Predator-B UAV used as a "flying laboratory."

- Fiber optics are installed on forward and aft section of both wings



Project: Ikhana



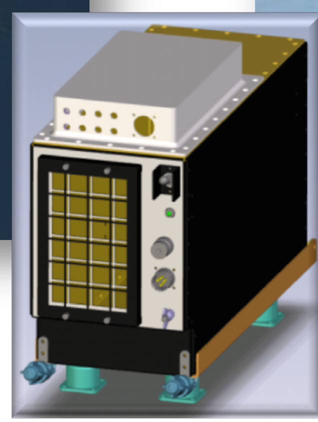
- Real-time strain data of the wing is captured during flight
- Strain data can be used for health-monitoring and feed-back control

Project: Composite Crew Module

- Four fibers were installed around the module's three windows and one hatch
- Real-time 3D strain distributions were collected as the module underwent 200%DLL pressurization testing
- Measured strains compared and matched well to predicted model results

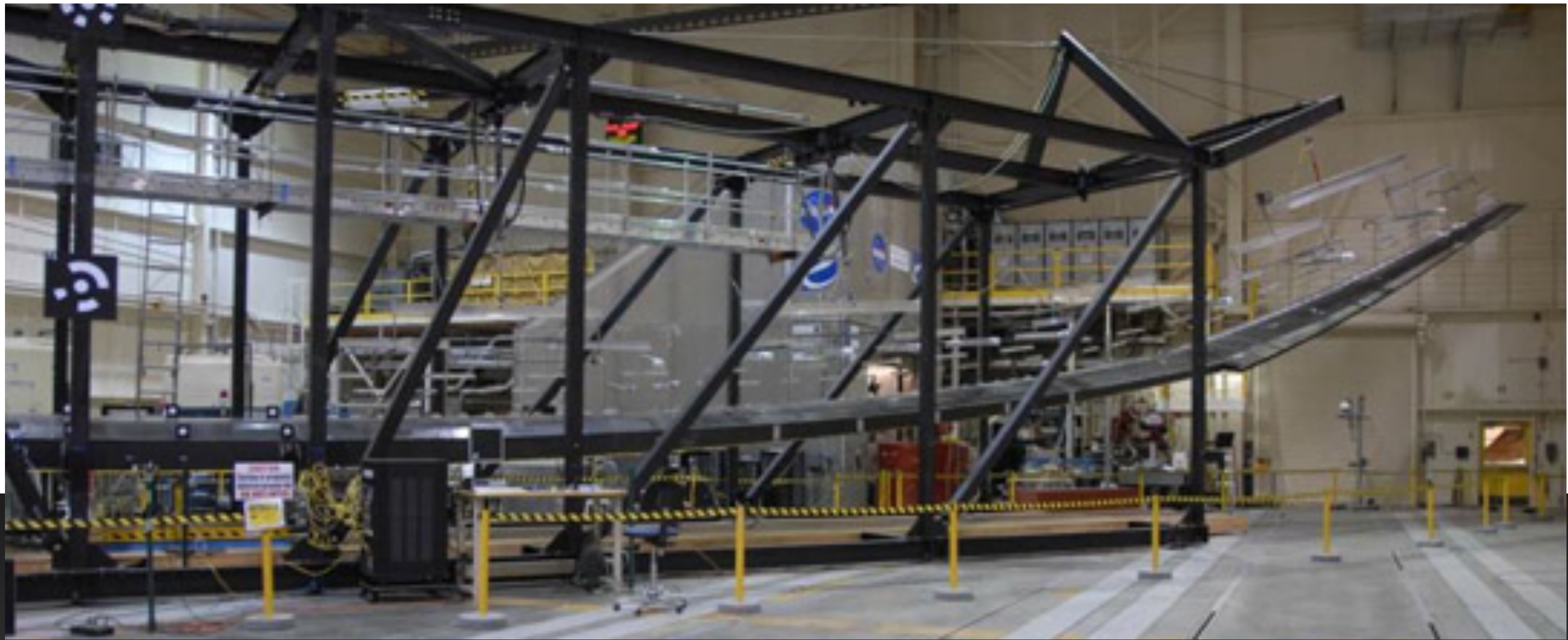
Project: Global Observer Flight test

- Global Observer is liquid hydrogen-powered UAV that is able to fly at 65,000 ft for up to seven days.
- Fibers Sensors (+8000) are installed along the left wing using 8, 40ft fibers
- An aft fuselage surface fiber was installed to monitor fuselage and tail movement
- Successful first flight at August 2010 with real-time strain sensing on-board.



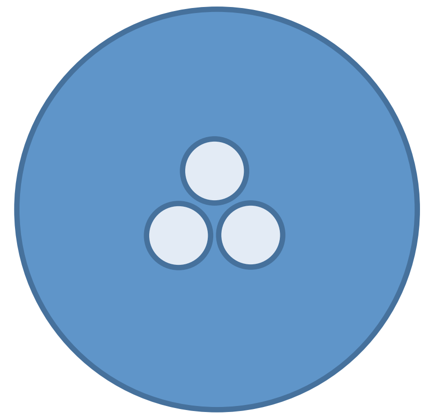
Project: Global Observer Ground test

- Validate strain predictions along the wingspan (185 foot) of the all-composite wing.
- Measured strain distribution along the centerline top and bottom as well as along the trailing edge top and bottom.
- A 24-fiber system was designed of which 18 fiber (~17,200 sensors) were used to instrument this wing

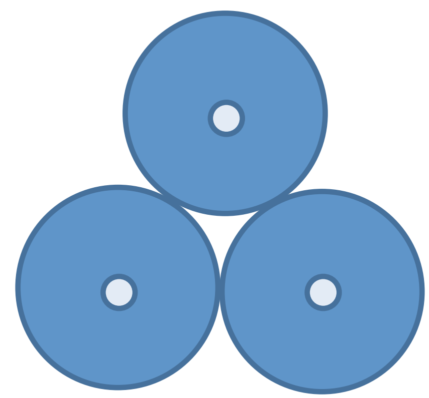


Alternative Method of Measuring Shape

- From collaboration with NASA Langley Research Center (LaRC), shape sensing using fiber strain sensors has been realized
- Initial research focuses upon 3-core fiber
- This specialty fiber can be replaced with 3 conventional fibers superposition from one another at 120 degrees
- From knowing the strain value of each fiber, the 3-dimensional position of the fiber can be correctly rendered in real-time



3 core fiber



3 SMFs aligned in 120°

Project Shape Sensing

Future Aerospace Projects

Fiber NASA Dryden's 853 (F-18)

- To determine the structural response to Aero and other forces
- Design and flight demonstration of structural feedback and shape control techniques
- Retro-fit current instrumentation is required to satisfy G-force of the F-18

Large scale implementation

- To instrument large vehicle (787) with multiple fibers sensors
- Goal: To provide an "one-box-system" capable of sensing 32,000 sensors simultaneously at 100Hz.

Future Projects beyond Aerospace

Structural health-monitoring of infrastructure

- "Smart structure " that has fiber embedded for health-monitoring
- Can determine material cracks develop beforehand for public safety.

Shape-sensing fiber

- Imagine "smart structure" that knows its shape as its change shape
- Implementing shape-sensing fiber into biomedical field (catheter)

However, we don't have all the answers

We NEED Help!

- **Mathematicians** and **Electric Engineers** for a faster/smarter algorithms that improves our system's interrogation speed.
- **Physicists** and **Optical Engineers** for a more compact/faster lasers so that we can further miniaturized our system.
- **Computer Programmers** for implementing our program for feedback control for flight systems and beyond.
- **System Engineers** to interface all the electronics with the optical fiber system and help with our miniaturization effort.

NASA needs students interested in Mathematics and Sciences!

Internship opportunity at NASA (intern.nasa.gov)

- Student On-Line Application for Recruiting Interns (SOLAR) **https://solar.nasa.gov/web/public/main/**
- Undergraduate Student Research Program (USRP) http://usrp.usra.edu/

Any other Advises?

- Don't be afraid of failure, because you will learn from it and overcome it.

-I am not discouraged, because every wrong attempt discarded is another step forward.

Thomas Edison